Topics for QCD modeling studies at an FCC-ee

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Future Circular Collider Study Kickoff Meeting
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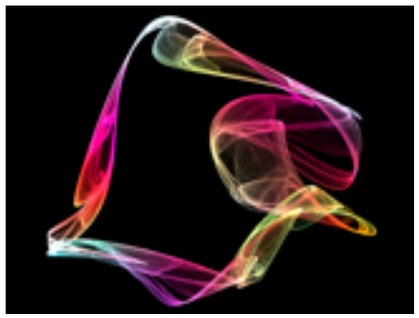
QCD at FCC-ee

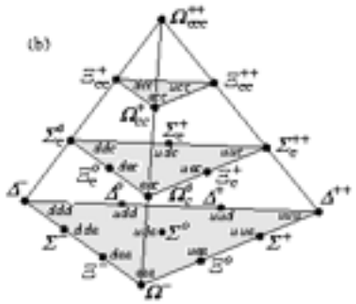
More than measuring α_s

Emergent phenomena

Jets (the QCD fractal) ⟷ amplitude structures (in phase space) ⟷ fundamental quantum field theory. Precision jet (structure) studies.



Strings (strong gluon fields) ⟷ quantum-classical correspondence. String physics. Dynamics of hadronization phase transition.



Hadrons (incl excited states) ⟷ Spectroscopy, lattice QCD, (rare) decays, mixing, exotic states (e.g Ω_{ccc}, hadron molecules, …), light nuclei

Existing Constraints

LEP/SLD (and other previous ee machines)

→ typically 5%-20% precision on QCD modelling constraints (Fine for LO+LL models of the 90'ies)

But **think** in context of physics models **20 years** from now!

Precise measurements really only up to 4 jets

Almost impossible to really access QCD fractal; subleading effects

LHC (and SPS, RHIC, Tevatron, …)

Fragmentation constraints not comparable to LEP/SLD

Complicated by additional issues in pp (eg UE), less clean
(Interesting physics overlaps with collective effects in heavy-ion)

Huge phase space for jets.

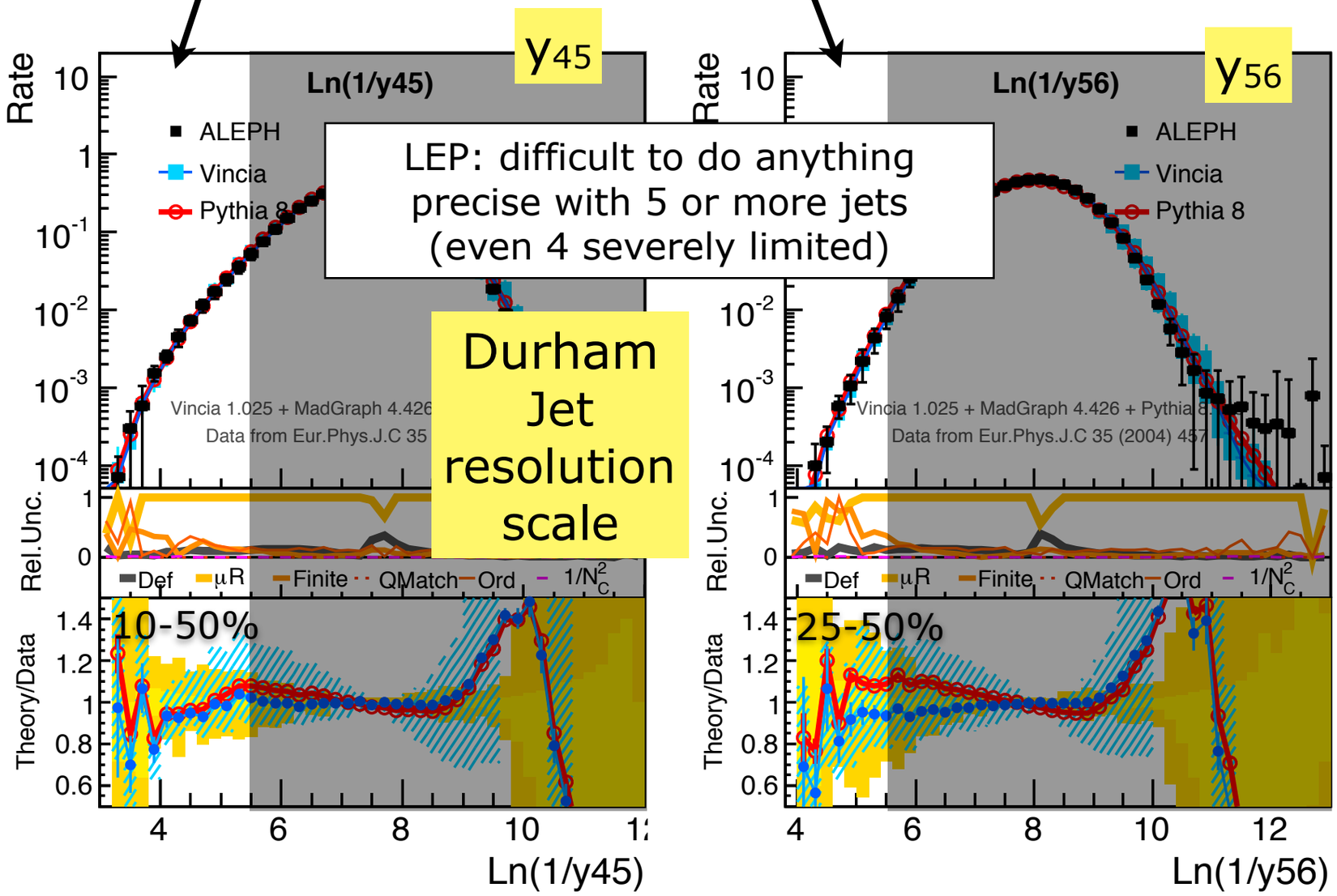
Will access QCD fractal. But complicated interplay with ISR & UE
E.g., subleading colour may be impossible to isolate

Jets: Some Examples

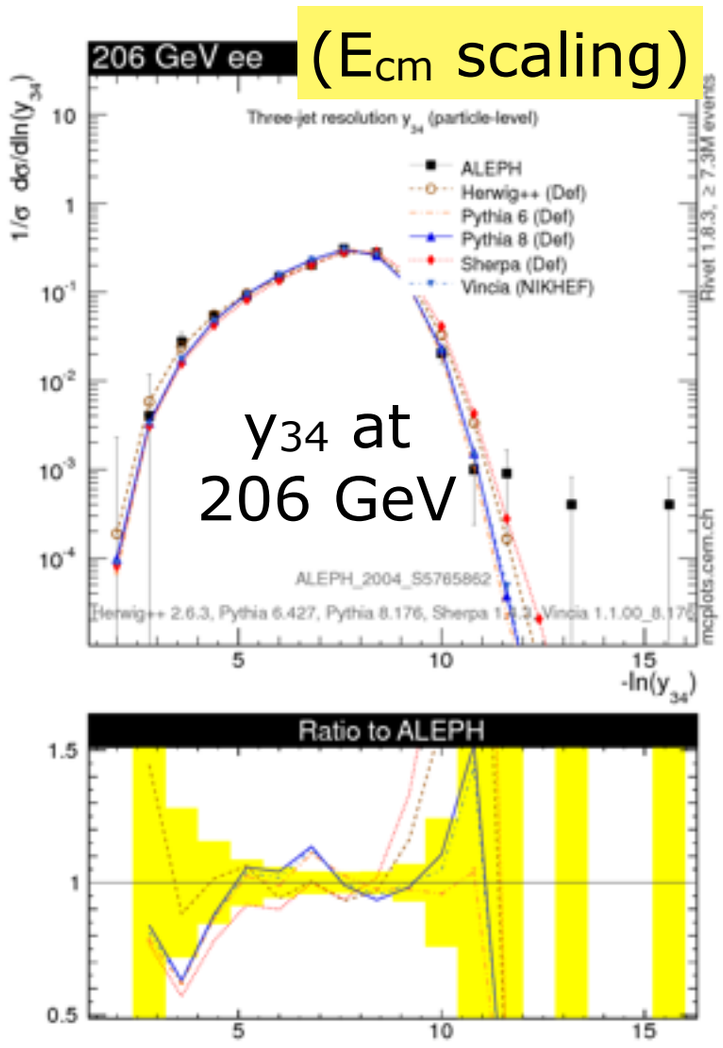
Aim should be: do 10 - 100 times better than LEP/SLD

Higher stats
Better detectors
Higher Q2

Hard Perturbative Region ($k_T \geq 5$GeV)



(E$_{cm}$ scaling)



Difficult to use for high-precision (< 10% i.e., beyond LO+LL) differential studies

Strings: Some Examples

Aim should be: do 10 - 100 times better than LEP/SLD

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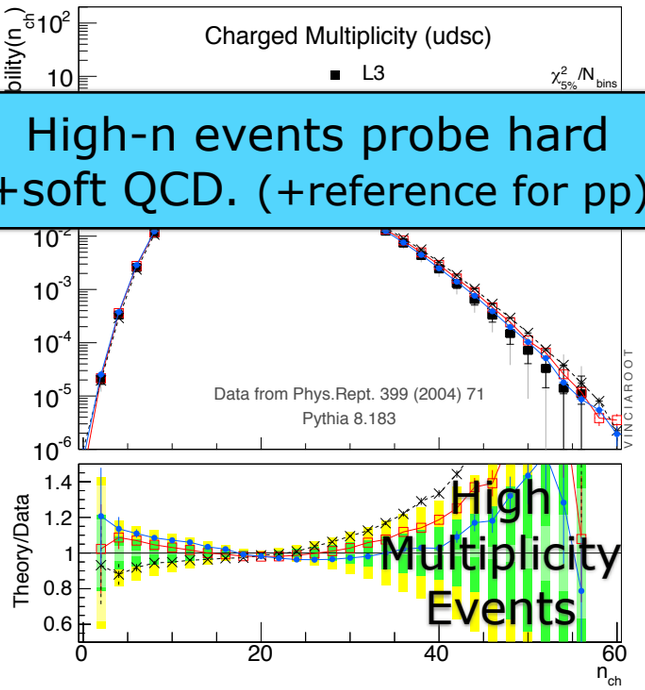
High-n events probe hard +soft QCD. (+reference for pp)



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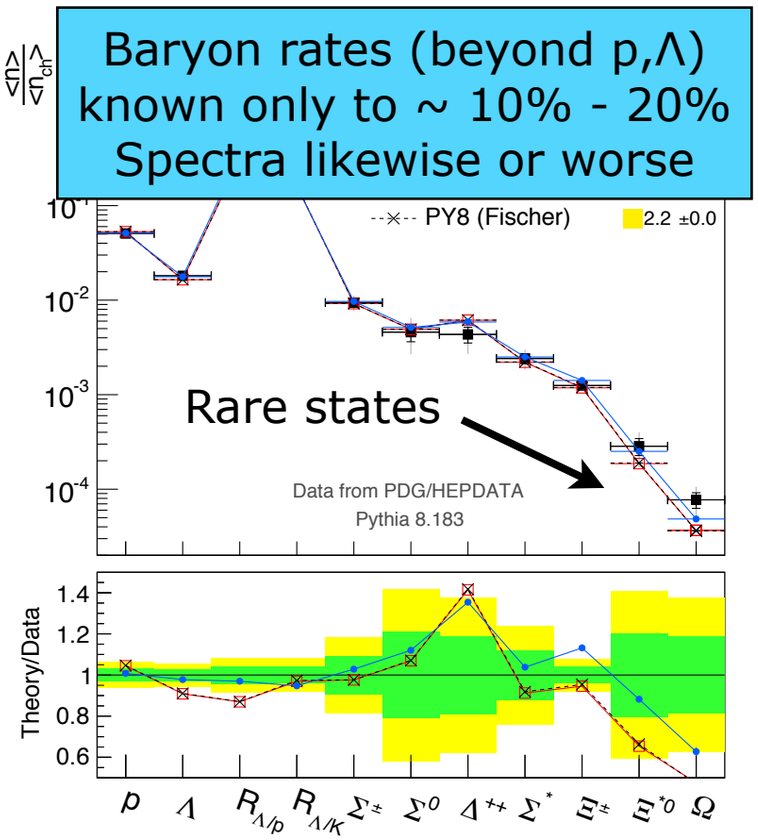
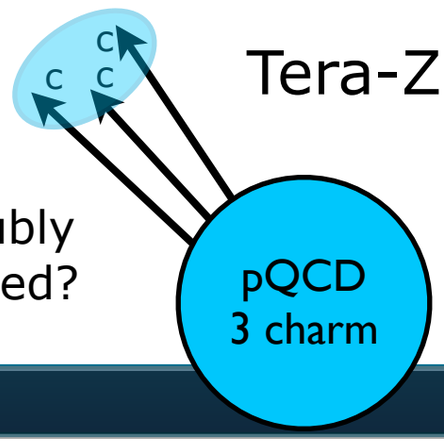
Baryon rates (beyond p,Λ) known only to ~ 10% - 20%
Spectra likewise or worse



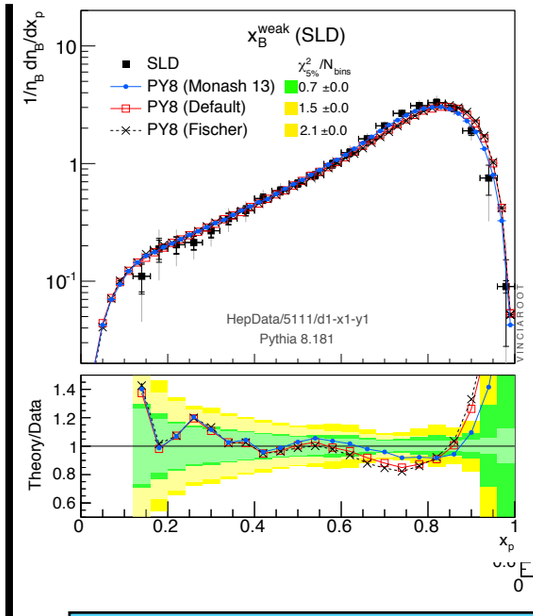
→ b and c baryons. What about Ω_{ccc} ?!

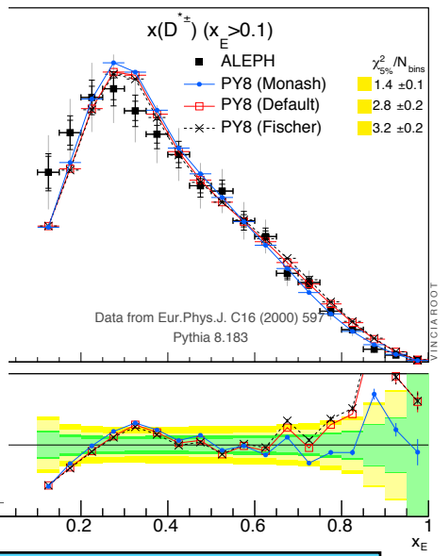


Tera-Z?

or doubly charmed?

pQCD
3 charm





D and B fragmentation
Few clean spectra
Uncertainties > 10%
Especially in soft and hard regions

+ Improve LEP limits on Colour Reconnections
→ clear signal?
→ STUDY colour reconnections
Feedback to pp

Future of QCD Models

Huge recent progress on theoretical side (not only cranking orders)

- Breaking through NLO (& automation) barrier
- Improving resummations and showers
- Better understanding of underlying principles (eg unitarity)
- Perturbative calculations combining different expansions

In 20 years, no one will be talking about "fixed order" calculations? → "perturbative" calculations, in form of:

- (N^nLO-corrected) (exclusive) (hadronized) Monte Carlos
- (N^nLO-matched) (inclusive) (analytical or numerical) resummations

These pQCD calculations will have very high precision

→ can see non-perturbative physics more clearly

Next generation models will have far better precision → need far better constraints. (And can probe far deeper! Reliably!)

Summary

Aim should be: do 10 - 100 times better than LEP

Higher lumi + better detectors

+ improve lever arm for **scaling** (→ 350 GeV)

+ FCC can also do lower energies in a hearbeat

Better (and standardized) analysis **tools**, better theory tools

Nail QCD fragmentation

Precision Jets: fractal structure, perturbative evolution, scale breaking, power corrections, coherence, isolating subleading colour corrections, subleading logs (compressed hierarchies), mass corrections, spin correlations, n-loop corrections, high-precision multijets, g→qq, IR limits …

+ Strings: hadronization, think in context of constraining the *next* fragmentation model, with much more precise perturbative input. Rates and fragmentation spectra at 1% level, with good resolution, also for rare/exotic states, in extrema of distributions, colour reconnections, …

+ Assuming you do all this → feedback to other WGs